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Reverse Engineering of the Multiple Launch Rocket System:

Human Factors, Manpower, Personnel, and Training in the Weapons System Acquisition Process

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In a briefing format, this report on the Multiple Launch Rocket System summarizes an examination of human factors, manpower, personnel and training (HMPT issues during the systems acquisition process. The report is one of four reverse engineering studies prepared at the request of GEN M. R. Thurman, Army Vice Chief of Staff. The four systems were studied as a representative sample of Army weapons systems. They serve as the basis for drawing conclusions about aspects of the weapons system acquisition process which most affect HMPT considerations. A synthesis of the four system studies appears in the final report of the Reverse Engineering Task Force, U. S. Army Research Institute.

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The Army is introducing new weapons systems to modernize its materiel resources at the greatest rate since World War II. At the same time, the Army is redesigning its force structure (Division 86) in light of the all-volunteer force. To insure that there will be enough soldiers with enough training to man the new complicated weaponry, the Army has designed a complex materiel acquisition process. This process is supposed to introduce human factors, manpower, personnel and training (HMPT) considerations into weapons system design early enough to prevent mistakes that will affect the system's operational utility and that will also add unanticipated expense to the weapon's life cycle costs.

Despite a number of regulations and instructions to include HMPT considerations in materiel acquisitions, the Weapons System Acquisition Process (WSAP) has not always been successful in producing weapons that are readily manned and operationally useful. This is true for several reasons. Techniques for predicting manpower requirements are not adequate. The documentation of HMPT requirements is slow and complicated, and it occurs too late in the WSAP to be effective. Finally, materiel developers often fail to understand the impact of HMPT requirements on the ultimate cost and operational utility of a new piece of hardware once it is fielded. Consequently, insufficient funds and effort are devoted to HMPT analysis and human factors engineering during early stages of system development. Such analyses have

often been scrapped when hardware budgets were exceeded and production schedules were slipping. Clearly, the WSAP needed more careful examination with respect to HMPT needs.

The Reverse Engineering Project was initiated at the request of GEN Maxwell R. Thurman while he was Deputy Chief of Staff for Personnel. It was his position that careful examination of the development process of several Army weapons systems that had already been fielded would identify critical events in the WSAP.

If proper consideration were given to HMPT issues at these critical WSAP events, the Army might be more likely to field more operationally useful systems. GEN Thurman began a series of projects to examine the WSAP. The U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) was already intensively involved in systems-manning technology research. ARI was assigned to do "reverse engineering" on four weapons systems: STINGER, Multiple Launch Rocket System (MLRS), BLACK HAWK (UH-60A), and the Fault Detection and Isolation Subsystem (FDIS) of the M1 tank. Reverse engineering is the process of examining a product of the WSAP and, by using documentation and data on the weapons system, to determine what was done with respect to HMPT issues and what else could or should have been done to improve the result.

Introduction to Reverse Engineering

This report is on the Multiple Launch Rocket System (MLRS). The report is self-contained, as are the reports on the three other weapons systems examined by the Reverse Engineering Task Force. There is also a report synthesizing the findings across the four weapons sytems and their implications for the WSAP.

It is not the intent of this report to criticize the MLRS or any of the agencies responsible for its development. It is intended, rather, that this effort focus the Army's attention on improvements that can be made in the weapons system acquisition process, by using the MLRS acquisition as an example.

BACKGROUND

The Army is introducing new weapons systems to modernize its materiel resources at the greatest rate since World War II. At the same time, the Army is redesigning its force structure (Division 86) in light of the all-volunteer force. To insure that there will be enough soldiers with enough training to man the new complicated weaponry, the Army has designed a complex materiel acquisition process. This process is designed to introduce human factors, manpower, personnel, and training (HMPT) considerations into weapons system design in a comprehensive fashion early enough to prevent manpower mistakes that will affect the system's operational utility or add unanticipated expense to the weapon's life cycle costs.

The Reverse Engineering Project was initiated at the request of GEN Maxwell R. Thurman while he was Deputy Chief of Staff for Personnel. It was his position that careful examination of the development process of several Army weapons systems that had already been fielded would identify critical events in the Weapons System Acquisition Process (WSAP). If proper consideration were given to human factors, manpower, personnel, and training issues at these critical WSAP events, the Army might be more likely to field more operationally useful systems. GEN Thurman began a series of projects to examine the WSAP. The U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) was already intensively involved in systems-manning technology research. ARI was assigned to undertake a study based on the

"Reverse Engineering" of four weapons systems: STINGER, Multiple Launch Rocket System (MLRS), BLACK HAWK (UH-60A), and the M1 Fault Detection and Isolation Subsystem (FDIS). Reverse engineering is the process of examining a product of the WSAP and, by using documentation and data on the weapons system, to determine what was done with respect to HMPT issues and what else could or should have been done to improve the result.

APPROACH

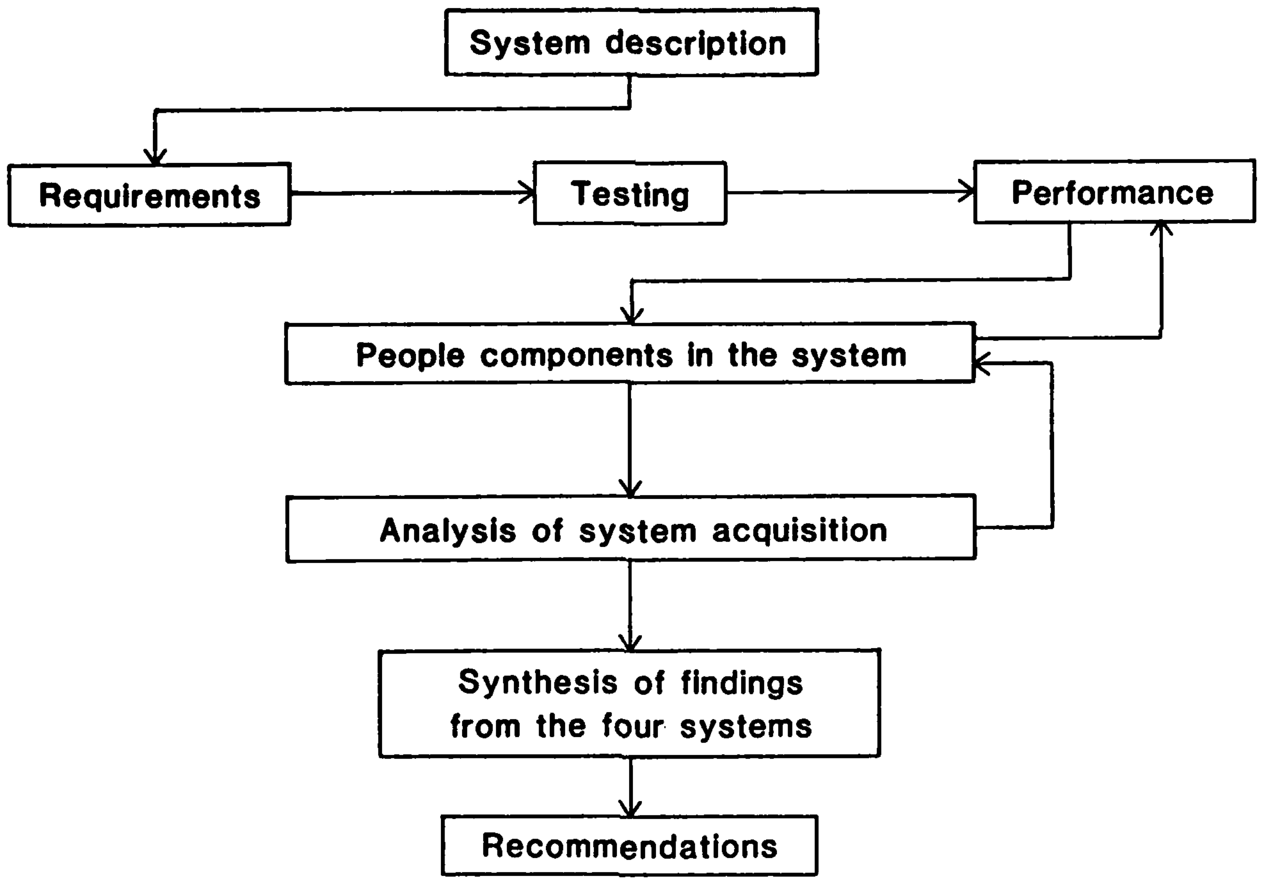
This report summarizes the study of the MLRS. Similar reports address the other three weapons systems encompassed by the Reverse Engineering Project. All four studies followed the same general approach illustrated in the figure below:

- The system was defined and described.
- Requirements documents were reviewed to determine how system performance was specified.
- Test and evaluation data were analyzed and compared to performance criteria.
- Problem areas in system performance were identified.
- HMPT factors were examined for their impact on the problematic aspects of system performance.
- The WSAP was reviewed to identify those facets that contributed to HMPT issues.

Findings from the four system studies were synthesized to arrive at conclusions regarding generic problems in the WSAP related to HMPT. Recommendations were developed for methods to improve the process

GENERAL APPROACH--REVERSE ENGINEERING

- STINGER
- Multiple Launch Rocket System
- BLACK HAWK
- M1 Fault Detection and Isolation Subsystem

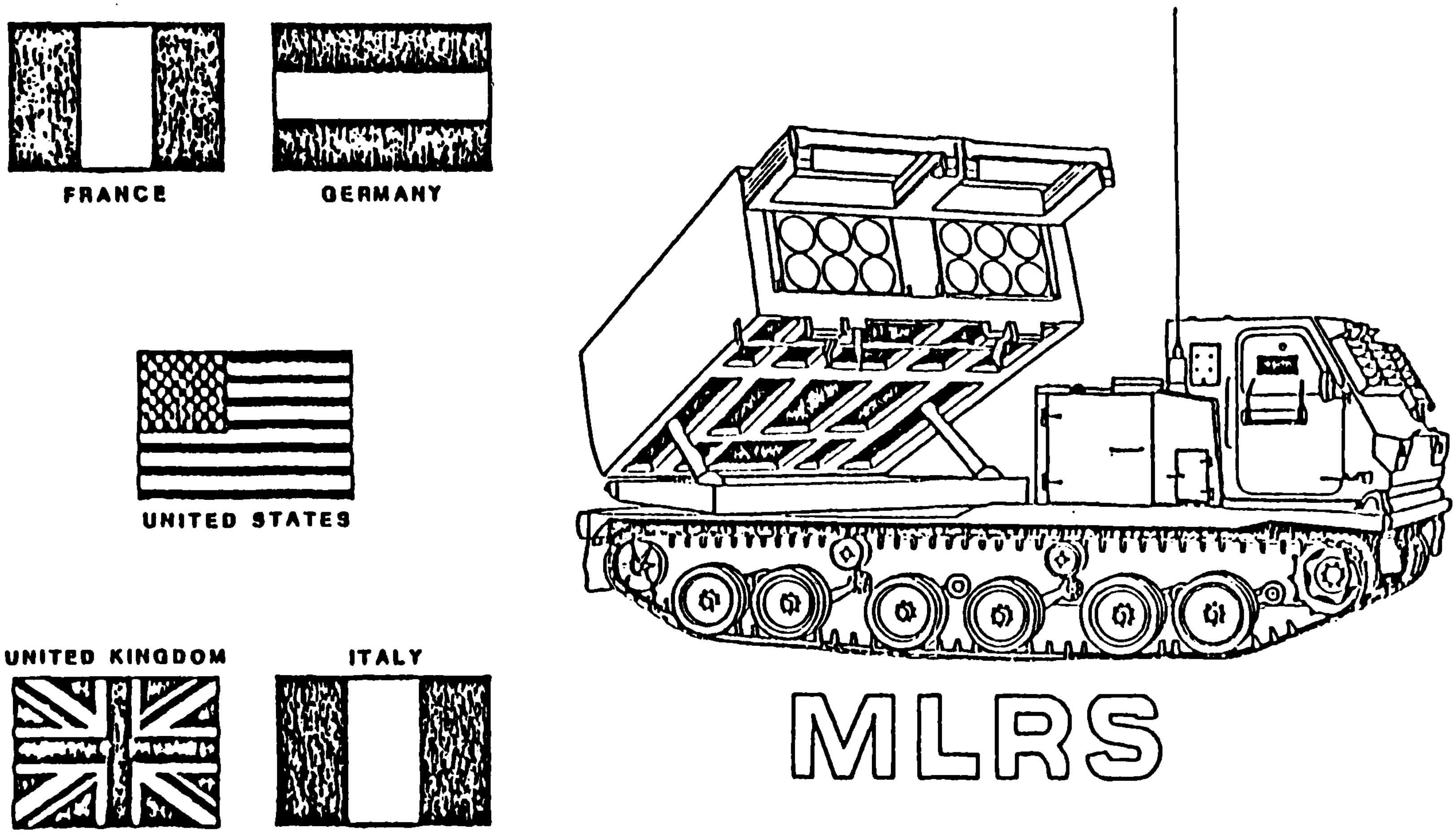


from an HMPT perspective. This information is summarized in the final report of the Reverse Engineering Task Force.

It is not the intent of the study or this report to criticize the M1 or any of the agencies responsible for its development. Instead, it is hoped that this effort will help focus the Army's attention on improvements that can be made in the weapons system acquisition process.

MAJOR FINDINGS

1. A comprehensive system description has never been developed for MLRS.
2. Requirements and system assessment have been addressed in terms of machine, not man-machine, system performance.
3. As a result, it is not clear what performance should be expected of MLRS.
4. Nevertheless, there are HMPT problems that affect system performance.
5. Most of these problems could have been forestalled if there had been a clear concept of the system.

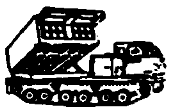

FRANCE
GERMANY
UNITED STATES
UNITED KINGDOM
ITALY
MLRS

Organization of this Report

This report on the Multiple Launch Rocket System (MLRS) summarizes, in a briefing format, an examination of human factors, manpower, personnel, and training (HMPT) issues during the Weapons System Acquisition Process (WSAP). The report is one of four reverse engineering studies prepared at the request of GEN Maxwell R. Thurman, Army Vice Chief of Staff. The four studies were selected as a representative sample of Army weapons systems. Together, they serve as the basis for drawing conclusions about aspects of the WSAP that most affect HMPT considerations. The synthesis of the system studies appears in the final report of the Reverse Engineering Task Force, U.S. Army Research Institute (ARI).

The presentation begins with a description of MLRS, focusing on those aspects of the system especially pertinent to soldier concerns. A brief description of the acquisition process is provided. Then there is an analysis of the relationship between system performance requirements, the outcome of MLRS test and evaluation, and soldier performance. Inferences are drawn regarding features of the acquisition process that contribute to HMPT issues. Major findings are presented.

OUTLINE



Multiple Launch Rocket System (MLRS) Description

Acquisition History

Requirements, Test and Evaluation, and Soldier Performance

Human Factors, Manpower, Personnel, and Training in the Acquisition Process

Major Findings

MLRS missions derive from a statement of need for a General Support Rocket System (GSRS):

"There is an urgent need for a rapid-fire, nonnuclear indirect fire weapon system to: (1) neutralize or destroy the enemy's indirect fire support, air defense capabilities and other light materiel/personnel targets, (2) perform other general support & special purpose fire missions, and (3) possess the growth potential so as to be adaptable to future developments in weapon technology to permit the attack of point and moving targets. The current nonnuclear indirect fire support capability is deficient in the following major operational areas: (1) inability to neutralize or suppress the enemy's massive indirect fire support and air defense capabilities in a timely manner, and (2) inability to attrit and defeat the overwhelming enemy armored maneuver force."

Source: *Letter of Agreement for the GSRS*, approved September 1975.

MULTIPLE LAUNCH ROCKET SYSTEM MISSIONS

- o Provide general support.
- o Complement standard cannon artillery in air defense suppression and counterfire roles.
- o Supplement other general support systems engaging high-density mechanized targets during *surge periods*.
- o Provide interdiction support against second echelon targets (troops, light equipment, target acquisition systems, air defense sites, logistics complexes, and command/control centers).

These missions are accomplished through employment of the MLRS battery which is capable of operating independently of parent headquarters for limited periods. Its major hardware components are:

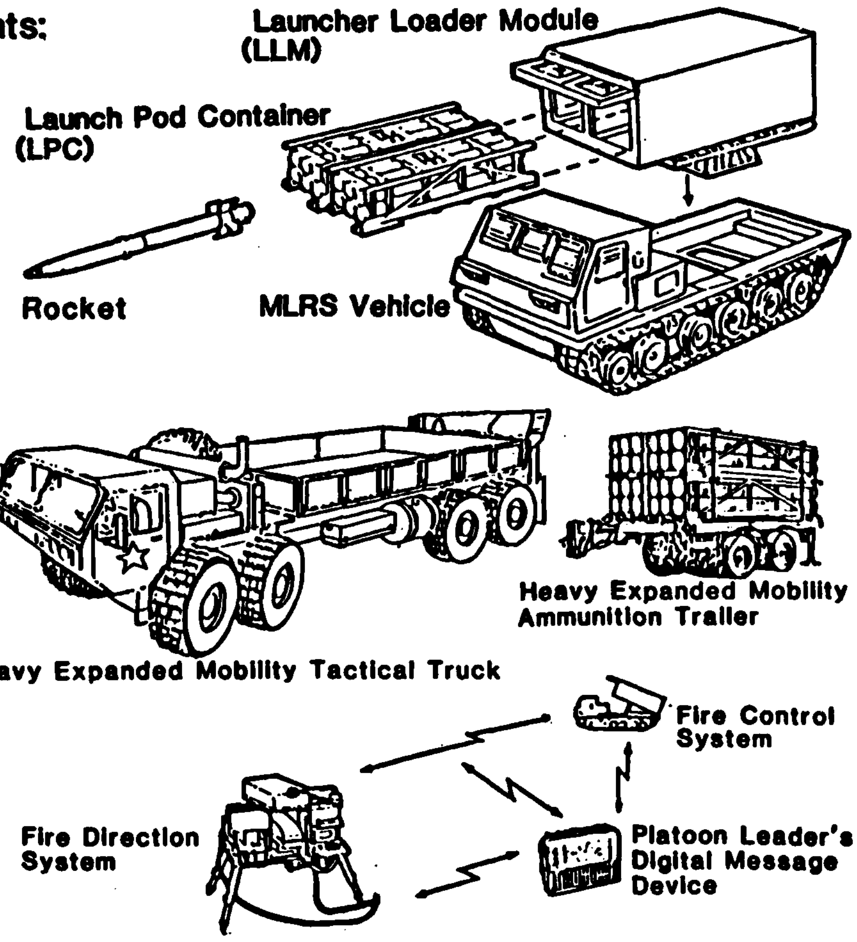
1. Self-propelled launcher loaders (SPLL) consisting of
   - Launch pod container (LPC),
   - Rockets packaged in two clusters of six each (two "six packs"), each rocket containing 644 submunitions, and
   - MLRS vehicle.
2. Resupply vehicles (RSV) and trailer
   - A heavy expanded mobility tactical truck (HEMTT), and
   - A heavy expanded mobility ammunition trailer (HEMAT).
3. A command, control, and communication system, including
   - Fire Direction System (FDS)--at battery level,
   - Platoon Leader's Digital Message Device (PLDMD)--one for each of three platoons, and
   - Fire Control System (FCS)--one in each of nine SPLLs.

Major System Components:

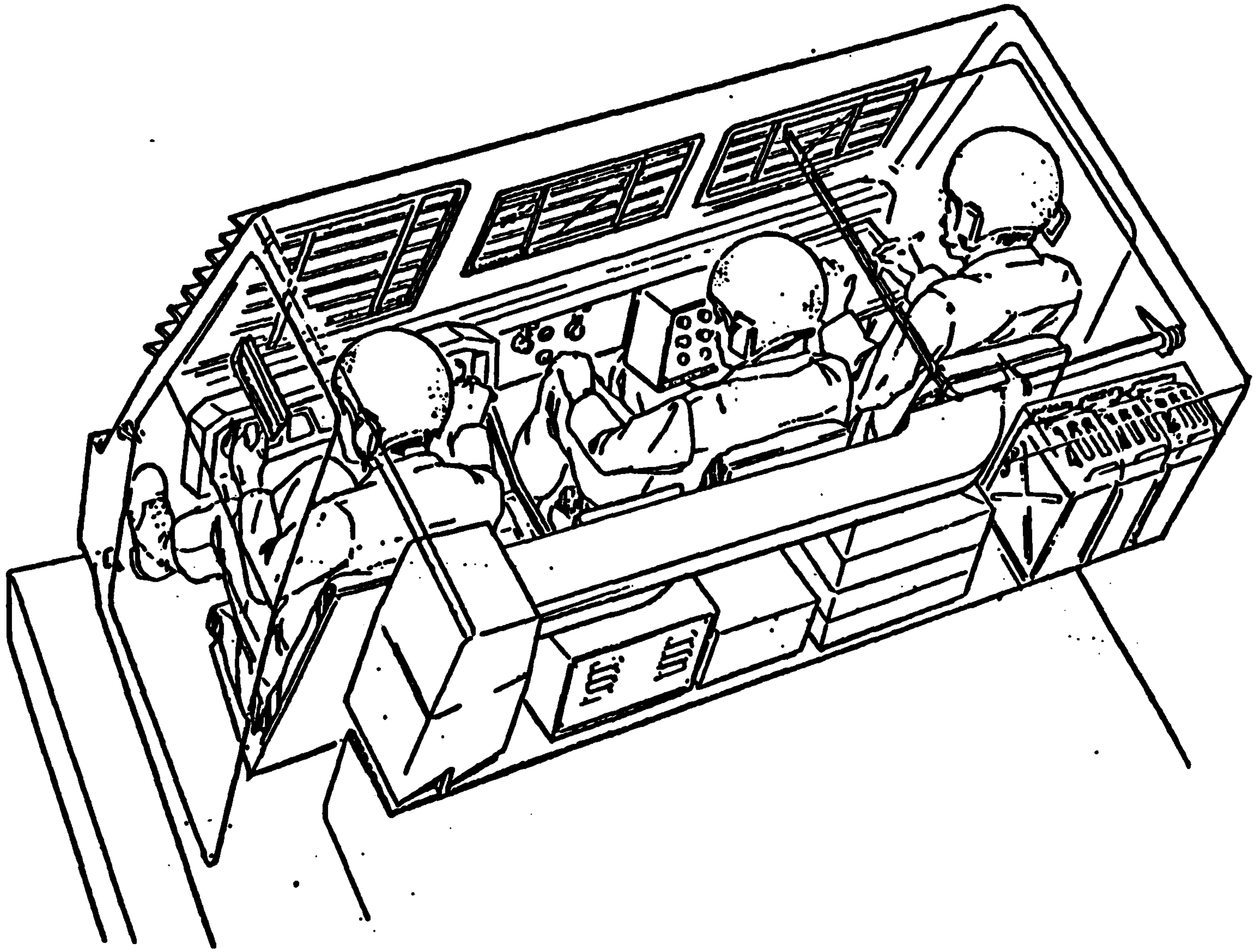
self-propelled launcher loader (SPLL)

resupply vehicle (RSV) and trailer

command, control, and communication system



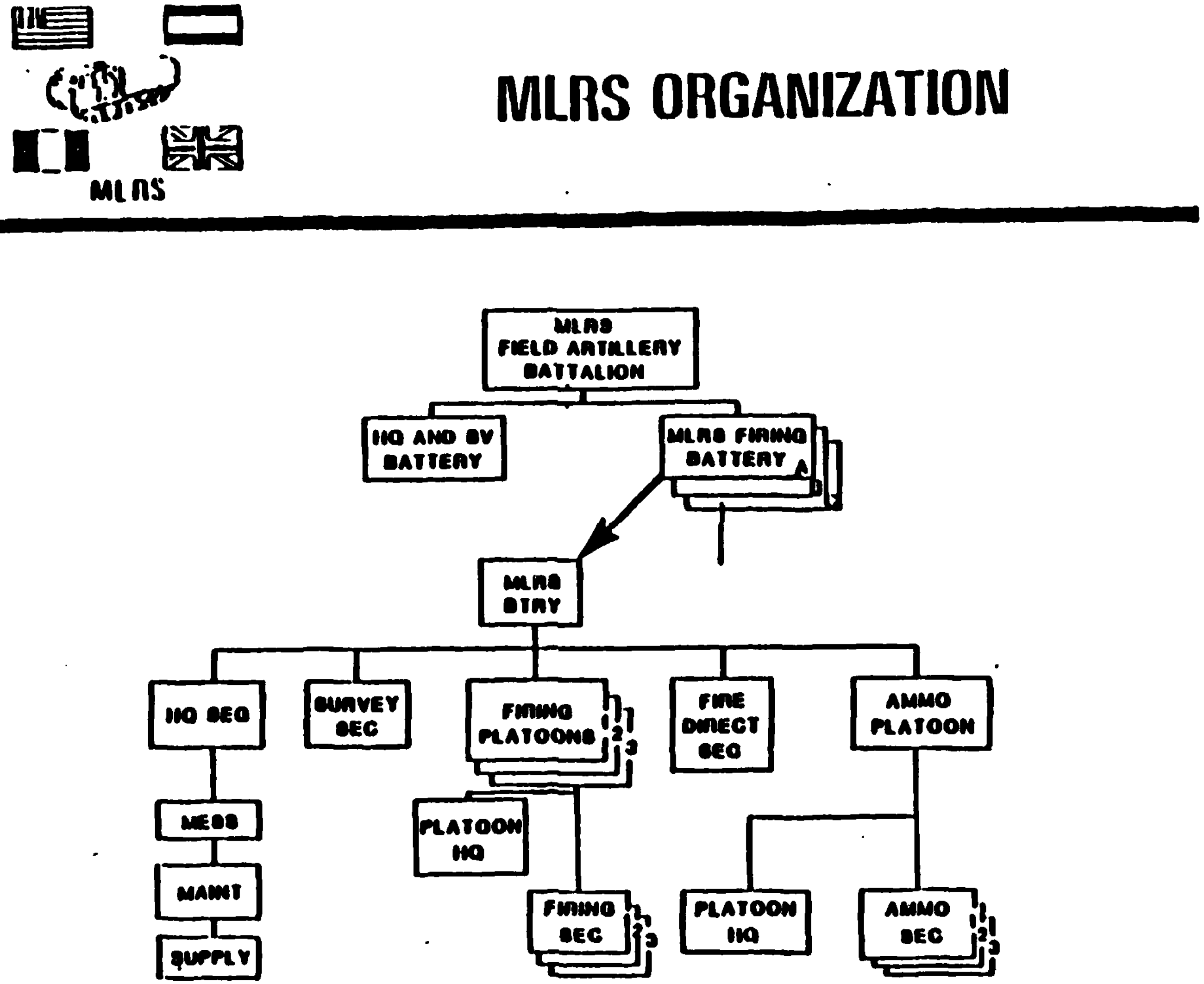
The core of the system is the SPLL, a highly mobile tracked vehicle that carries two launch pod containers of six rockets each, i.e., two "six packs." The SPLL is manned by a crew of three, consisting of the section chief, gunner, and driver. Fire control calculations and rocket launching are completely automated functions.



Interior Cab of SPLL

The basic unit of the system is the MLRS battery, which is largely autonomous. It is combined with other units to create a variety of organizational configurations. An MLRS battery contains three firing platoons, each containing three firing sections, a total of nine SPLLs. Other key battery elements include the fire direction section, survey section, and ammunition platoon.

MLRS ORGANIZATION

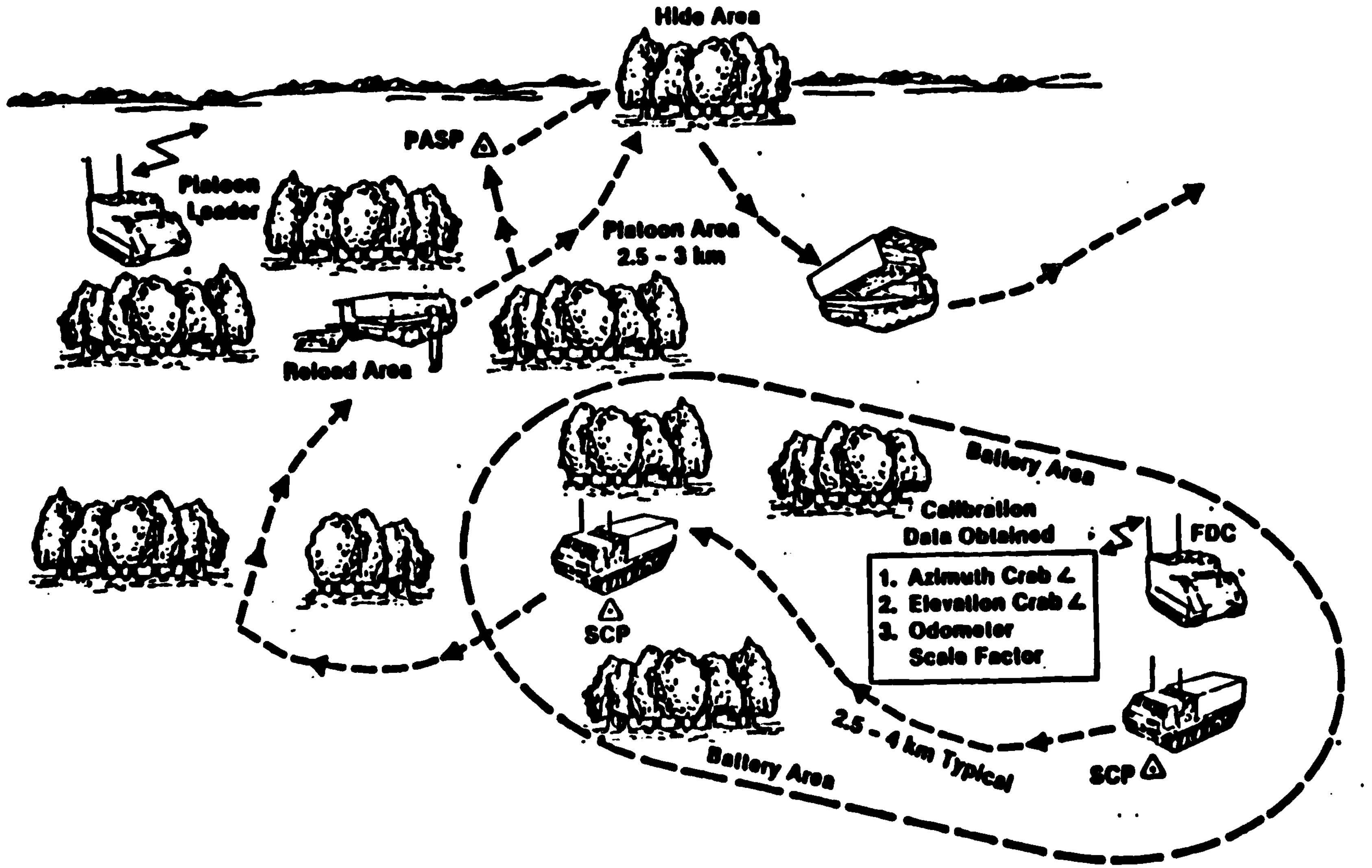


Operation of a battery is a complex matter involving many functions, much movement, and large geographic areas. The current concept of MLRS operations is characterized by:

- Each of the firing platoons occupying an area approximately 1.5 x 2.0 km;
- Use of several hide areas, firing areas, and reload areas by each SPLL;
- Precise positioning information required for each SPLL with monitoring by the platoon leader;
- Fire mission assignments made by the fire direction center directly to the SPLL;
- Fire control calculations performed by computer in each SPLL;
- Rapid SPLL movement to firing area and from firing area to leave vulnerability zone, i.e., "shoot and scoot"; and
- Extensive use of resupply vehicles to keep resupply points stocked with rockets.

Sources: As presented in such documents as *MLRS System Organization, Tactics, & Techniques Concept for OT III*, June 1981, and *Multiple Launch Rocket System Operations*, FM 6-60, 1983.

Operational Scenario (Typical)



The MLRS maintenance concept is based upon maximum utilization of the typical four levels of maintenance without the addition of specified maintenance organizations or detachments. Operator functions include operation checks, authorized adjustments, preventive maintenance, and minor repairs. Organizational maintenance is performed by MLRS battery maintenance personnel assisted by operators as required. Direct support functions include both maintenance and supply. During field exercises and combat operations, direct support maintenance support teams from the missile maintenance company will usually be located at the firing battery to provide on-site repair. General support capability will be at the corps level. Depot maintenance support will be established in Europe and the continental United States. Interim contractor support is being used.

(U) MLRS MAINTENANCE CONCEPT (LESS CARRIER VEHICLE)				
TOPICS	**DEPOT**	**GENERAL SUPPORT**	**DIRECT SUPPORT**	**ORGANIZATION**
Tools and Test Equipment Available	Automatic Test Equipment Common & Special Tools Cable Testing Equipment	Automatic Test Equipment Common & Special Tools Cable Testing Equipment	BITE Common Tools Common Test Equipment	BITE Common Tools
Level of Troubleshooting	Fault Isolate PCB to Component Level Overhaul Rebuild Cable Connector Repair	Fault Isolate Elec. Modules to PCB Level Repair of Selected Electro/Hyd/Mech Assemblies Remove & Replace Most Cable Assemblies	Fault Isolate when Remove & Replace Fails to Correct Symptom Repair of Selected Electro/Hyd/Mech Assemblies Remove & Replace Most Cable Assemblies	Services, Lubrication, Remove & Replace Some Modules Remove & Replace Some Cabling

Source: *MLRS Master Program Plan*, 31 March 1983.

To fulfill its mission, the MLRS battery must perform several functions, all involving people and machines in varying degrees. For example, detonating submunitions on target is largely independent of human action except under circumstances that call for manual computer data entry. Target assignment to the SPLL is a human decision-making task; ammunition resupply depends upon truck driving and soldier land navigation, etc.

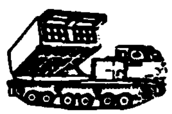
The array of battery elements required to supplement SPLL in the performance of the above functions proves that MLRS is a complex, multi-component system. The SPLL is the first field artillery weapon designed with an on-board control, orientation, and position-locating system.

MLRS Functions	Required System Elements
Detonate submunitions on target	SPLL, Fire Direction Center, Communications
Launch rockets	SPLL, Fire Direction Center, Communications
Place SPLL in position to engage targets	Battery RSOP, Platoon RSOP, SPLL, SPLL crew land navigation
Assign targets to SPLL	SPLL, Fire Direction Center, communications, platoon command and control
Keep SPLL supplied with rockets	Battery ammunition platoon, resupply vehicles (RSV), RSV driver land navigation, SPLL, SPLL crew land navigation, battery RSOP, platoon RSOP
Protect SPLL when not engaging targets	SPLL, SPLL crew land navigation
Maintain SPLL availability to engage targets	Battery command and control, platoon command and control, battery direct support maintenance, SPLL crew maintenance

<u>The SPLL Must Be Properly Integrated into a Firing Battery If It Is To Have Any Value in Combat</u>

OUTLINE

Multiple Launch Rocket System (MLRS) Description



Acquisition History

Requirements, Test and Evaluation, and Soldier Performance

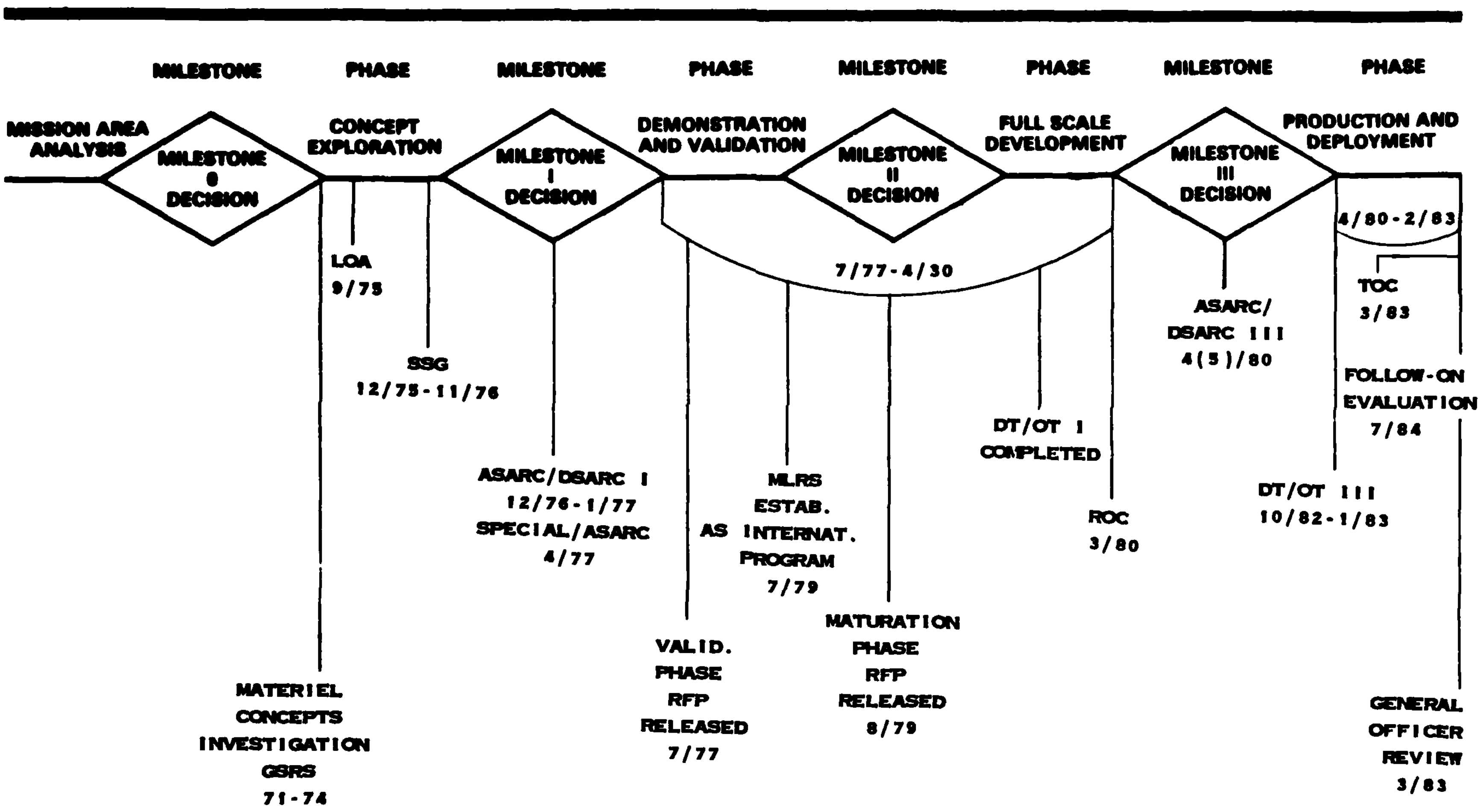
Human Factors, Manpower, Personnel, and Training in the Acquisition Process

Major Findings

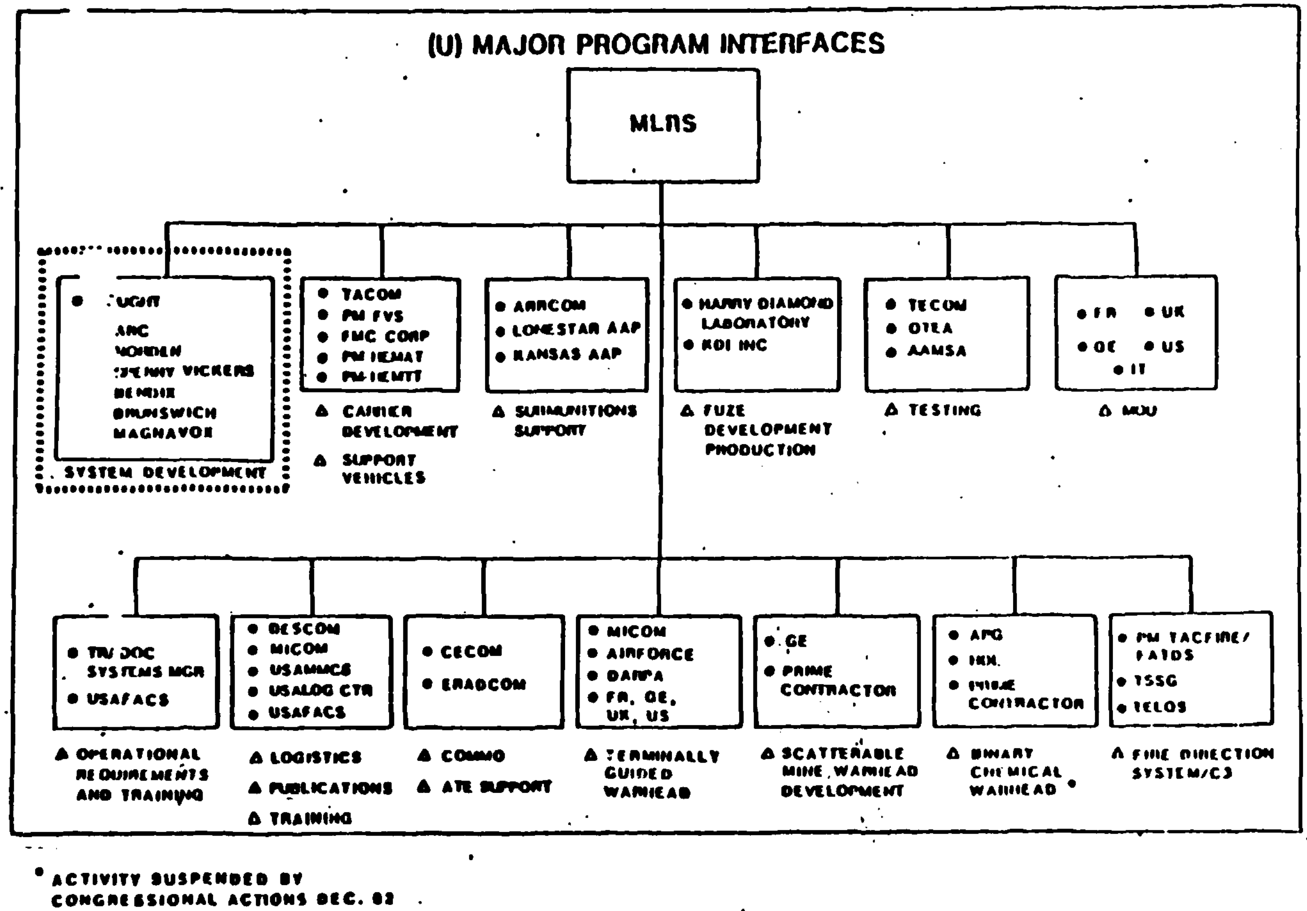
The Acquisition Phases and Milestones Chart shows the MLRS program history compared with the standard sequence of Life Cycle System Management Model (LCSMM) events. The MLRS (initially referred to as the General Support Rocket System or GSRS), began in FY 71 with a study of the 1980-1990 battlefield conducted by the Institute for Land Combat and the Army Materiel Concept Agency. A task force BATTLEKING study completed in December 1974 led to a letter of agreement (LOA) for MLRS that was approved in September 1975. As a result of Army System Acquisition Review Council (ASARC) I, Defense System Acquisition Review Council (DSARC) I, and a special ASARC from December 1976 to April 1977, the development of MLRS was authorized under an accelerated program. The program's object was to achieve Initial Operational Capability (IOC) within 60 months. The acceleration merged the demonstration and validation phase with the full-scale development phase of the LCSMM and eliminated the Milestone II decision. In early 1980, two competitive development contracts were awarded for a validation phase leading up to Development Test (DT) I, Operational Test (OT) I, and ASARC III/DSARC III. In July 1979 a memorandum of understanding on a cooperative program for a Medium Multiple Launch Rocket System was signed by Germany, France, the United Kingdom, and the United States. This action was supplemented by an agreement with Italy in 1982. A Required Operational Capability (ROC) was submitted to Headquarters, Department of the Army, in August 1979 and received approval in March 1980. The MLRS maturation and initial production phase began in April 1980 with contracts awarded to the Vought Corporation. Force Development Testing and Experimentation (FDTE) was scheduled to occur just prior to DT/OT III but was cancelled. The DT/OT III were held in late 1982 through early 1983. A general officer review in March 1983 led to the decision for full-scale production and the requirement for a follow-on evaluation to be completed by July 1984.

MLRS

MAJOR ACQUISITION PHASES AND MILESTONES



The complexity of MLRS is matched by the number of major program interfaces. Five program managements (PMs) and five countries are involved in MLRS development.

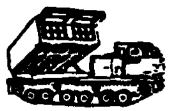


Source: *MLRS Master Program Plan*, 31 March 1983.

OUTLINE

Multiple Launch Rocket System (MLRS) Description

Acquisition History



Requirements, Test and Evaluation, and Soldier Performance

Human Factors, Manpower, Personnel, and Training in the Acquisition Process

Major Findings

Does the MLRS meet expectations? This question will be addressed for several system characteristics selected because of the impact of soldier performance on them. Stated system requirements will be reviewed and compared with the available data describing performance. An assessment will be made of the extent to which conclusions can be reached regarding the adequacy of system performace. Then the relationship between soldier and system performance will be addressed.

MLRS requirements documents refer to a series of system "characteristics" rather than functions. There is no one-for-one relationship between the two methods of description. The charateristics reviewed here were selected because of their importance to operations and the potential impact HMPT may have on them.

SYSTEM CHARACTERISTICS SELECTED FOR REVIEW AND THEIR RELATION TO SYSTEM FUNCTIONS

Functions	Characteristics					
	System Accuracy	System Reaction Time	Command, Control, and Communications	Ammunition Resupply	Reliability Availability, and Maintainability (RAM)	System Effectiveness
Detonate submunitions on target			X		X	X
Launch rockets	X	X	X	X	X	X
Place SPLL in position to engage targets	X	X	X		X	X
Assign targets to SPLL	X	X	X		X	X
Keep SPLL supplied with rockets		X	X	X	X	X
Protect SPLL when not engaging targets		X	X			X
Maintain SPLL availability to engage targets		X	X		X	X

Accuracy requirements are presented in greatest detail in the system specification. That document and the ROC refer to the relationship between system accuracy and SPLL position determination. However, the system specification is the only document that alludes to the relationship between time and accuracy for position determination.

SYSTEM ACCURACY

Requirements

LOA	Accuracy is a function of range and system design--to be postulated in concept definition and demonstrated in advanced development.
System Specification	Accuracy goals specified in terms of circular probable error for precision, bias, and total error as a function of range. Required a position determining system to provide data "with an accuracy and within a timeframe sufficient to satisfy system accuracy and reaction time requirements, respectively."
Required Operational Capability	Circular error probable specified for one range band. Required onboard position determining system "to locate the launch point to the accuracy required by the system design."

Test data show that MLRS did not meet its firing accuracy requirements. There were soldier errors related to firing accuracy during testing. However, their impact is unknown because they were corrected by test personnel prior to live firings.

SYSTEM ACCURACY

Test and Evaluation

Firing accuracy appeared adequate in early testing but was inadequate in later testing.

	OT	DT
I	Accuracy reported to have achieved user's goal.	Accuracy reached criterion in one range band but not others.
III	The single criterion value was not met in 118 of the 132 firings.	Criteria were not met in any of three range bands used.

The principal impact of soldier performance on rocket accuracy relates to the tasks of positioning the SPLL for engagement and obtaining accurate position information for the fire control solution.

SYSTEM ACCURACY

Soldier Performance

- The AMSAA Independent Evaluation Report (validation phase) concludes, based on its analytical modeling studies, that MLRS performance (i.e., rocket accuracy) shows "a significant sensitivity to survey error." Furthermore, it states that "aiming error induced by human interface with the GSRS" should be determined.
- In its IER for OT III OTEA concludes "The frequency & distribution of the radial error [of SRP/PDS readings at the launch point] . . . is not considered satisfactory" even though "no criterion *had* been established prior to OT III."
- Crew failure was cited as a possible cause for the inaccuracies noted during OT III, and special instructions were given SPLL crews during the testing, emphasizing proper update and calibration procedures for the SRP/PDS equipment.
- In addition, problems were reported with azimuth errors when crews in OT III located SPLLs on slopes of more than 5 degrees.
- The Program Management Office in a recent meeting with ARI has commented on the need for a SPLL crew chief sufficiently experienced to note at least gross errors in positioning. This apparently was not always the case during testing.

In summary, soldier impact on rocket accuracy is a source of concern that should be carefully measured. Attendant HMPT issues also should be addressed.

SYSTEM ACCURACY

Soldier Performance

- There is evidence of inadequate crew performance with regard to SPLL positioning during testing.
- Testing agencies did not systematically observe human performance with SPLL positioning and did not describe the human errors that were noted.
- Therefore, the full range of HMPT problems impacting on crew performance has not been identified.
- However, it is clear that improved training is required.

Required reaction times were specified for only a portion of MLRS operations.

REACTION TIME

Requirements

- Requirements documents address reaction time only in terms of the engagement sequence and RAM, e.g., mean time to repair.
- Requirements documents provide little guidance in assessing the relation of performance time to correctness of performance.
- Testing agencies were more comprehensive in the system functions addressed but did not correlate performance time with correctness.
- In particular, the only reference to the relationship between accuracy of SPLL positioning and the associated reaction time was in the system specification. The relationship was not evaluated in testing.

Delineation of MLRS doctrine and operational and organizational concepts have evolved throughout the development process. The engagement sequence and the steps for which reaction times were specified reflect this. Although these concepts expanded from the time of the LOA through OT III, specifications in requirements documents remain incomplete. Furthermore, definitions of steps in the engagement sequence, both as specified and measured, were somewhat ambiguous.

REACTION TIMES

Engagement Sequence (Based on FM6-60, MLRS Operations, 1983)	Requirements LOA	Requirements System Specification	Requirements ROC	Tests OT III
Receive fire mission at battery and transmit to SPLL	-	-	-	X
Receive fire mission at SPLL	-	-	*	X
Travel from hide area to launch point	-	-	-	X
Emplace launcher	X	X	X	X
Fire rounds	-	X	X	X
Displace launcher	X	X	X	X
Travel to reload point	-	*	*	X
Reload launcher	X	X	X	X
Report SPLL status and location	-	-	*	-
Travel to hide area	-	-	-	X (OT I)
Mission cycle	-	X	X	X

X--Reaction time specified or measured

*--Task included in definition of mission cycle but reaction time not specified

Conceptual and measurement problems make it difficult to assess the adequacy of current system reaction time performance.

REACTION TIME

<u>Test and Evaluation</u>

- Test data indicate that reaction time performance in the engagement sequence was close to that required for those steps where criteria were specified.

- However, reaction time for the engagement sequence as it is currently defined clearly exceeds mission cycle time criteria contained in requirements documents.

- Test and evaluation of reaction time was based on dry firings. However, OT III data show that the median time from arrival at the launch point until firing the first round was about eight times greater for live firing than dry firing.

Reaction time in the engagement sequence is very much a measure of man-machine performance. It is difficult to assess the adequacy of both system performance and soldier performance.

REACTION TIME

<u>Soldier Performance</u>

- The reaction time performance consistent with specifications in requirements documents may be attributed in large part to the design of the SPLL from an HMPT perspective.

- The increased reaction time for live firings relative to dry firings appears to be an HMPT issue, but the available test data do not permit a definitive diagnosis. Test personnel speculate that this time differential will decrease as crews gain proficiency, i.e., with more training.

- The potential value of improved crew training is also indicated by the decrease in engagement sequence reaction time between Field Exercises I and II of OT III.

Initially, MLRS command, control, and communications (C^3) was assumed to be analagous to prior artillery systems. Later requirements documents did little more than list major items of hardware.

COMMAND, CONTROL, AND COMMUNICATION (C^3)

Requirements

SSG Report	"C^3 functions should be patterned after those functions used with cannon units. GSRS will be tied into TACFIRE using the Battery Computer System."
System Specification	"MLRS shall interface and be compatible with C^3 systems of the time frame." Specified an FDC organic to MLRS organization to "provide automation of selected functions" and a digital data device organic to MLRS platoon "for controlling SPLL's and in putting digital data . . . into the FDC."
Required Operational Capability	"The C^3S system consists of SPLL onboard computer and fire control equipment . . . platoon leader's digital message device: to monitor fire missions . . . the battery computer system which will be located at the MLRS battery and battalion FDC."

Despite the lack of specific system performance requirements, OT III personnel felt that C^3 performance was problematic.

COMMAND, CONTROL, AND COMMUNICATIONS

Test and Evaluation

MLRS performance was found in OT III to be adversely affected by

- o Lack of adequate communications among the SPLL, platoon, and battery headquarters,
- o Excessive time in processing fire missions by the battery fire direction system,
- o Inefficiency during surge conditions and lack of mobility of battery headquarters.

More specific examples of problems noted in OT III are given below.

COMMAND, CONTROL, AND COMMUNICATIONS

Test and Evaluation

OT III:

- o Fire Direction System (FDS) processing time (when there was no backlog) was excessive 46% of the time--attributed to administrative and logistics traffic on the digital net.
- o FDS was considered adequate for tactical planning, but expanded software would be required for conducting battery operations.
- o The PLDMD did not adequately accomplish its mission in support of the platoon leader--attributed to hardware and software failures.
- o During surge conditions, effectiveness of battery mission and service support operations decreased to an unsatisfactory level.
- o Battery headquarters should be as flexible and dynamic as SPLL platoons and was not.
- o Digital communications among SPLL, platoon, and battery headquarters rated by soldiers as inadequate to borderline.

HMPT problems contribute to inadequate system C^3 performance.

COMMAND, CONTROL, AND COMMUNICATIONS

Soldier Performance

- Soldier performance at battery, platoon, and SPLL levels is inhibited by the need to compensate for inadequate software (OT III, HEL study,[1] users' comments[2]).

- The FDC needs more personnel (OT III, users' comments[2]).

- Improved operator training is needed in such areas as fire planning, support coordination, care and troubleshooting of communications equipment, electronic warfare operations (OT III, HEL study[1]).

- There are human engineering problems with the FDC (HEL study[1]).

- ARI has found no documentation describing the skills or abilities needed for FDC or platoon personnel.

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[1] Dempsey, H.A.L. *Dispositions of Human Factors Findings of the Multiple Launch Rocket System Fire Direction System*, U.S. Army Human Engineering Laboratory, September 1981.

[2] Cummings, M. J., & S. C. Preczewski "New Kid on the Block," *Field Artillery Journal*, September-October 1983.

The system specification and ROC make no reference to the amount or rate of ammunition resupply required. As in the case of C^3, there was reliance on reference to "conventional" procedures as a description of resupply requirements.

AMMUNITION RESUPPLY

Requirements

SSG Report	Projected ammunition supply rate for extended combat is seven launcher loads per launcher per day. Normal method will be throughput distribution of ammunition to preselected delivery points (ASP) as far forward as possible. Battery resupply vehicles will transport LPCs from ASP to firing positions.
System Specification	RSV shall be capable of carrying four LPCs while towing a trailer also carrying four LPCs. RSV shall contain a modular, self-contained powered, boom/crane.
ROC	Transportation, storage, and handling of the loaded LPC shall be in consonance with existing conventional ammunition procedures.

Despite the lack of emphasis in requirements documents, both the Army Materiel Systems Analysis Agency (AMSAA) and the Operational Test and Evaluation Agency (OTEA) have expressed concern about degradation of MLRS performance as a result of ammunition problems.

AMMUNITION RESUPPLY

Test and Evaluation

- Lack of logistical support and, in particular, ammunition resupply could seriously constrain the capability of MLRS (AMSAA IER, Validation Phase).

- The ability of the MLRS battery to resupply itself on the battlefield is the primary concern in the logistics area (OTEA IER, OT III).

HMPT problems contribute to potential ammunition resupply problems.

AMMUNITION RESUPPLY

Soldier Performance

- "Human error in managing available assets ... despite the dynamic environment" contributed to nonavailability of ammunition (OTEA IER, OT III).

- Software available for the PLDMD in OT III did not provide information necessary for platoon leader to manage incoming RSVs and deploy them to correct location for SPLL resupply (OTEA IER, OT III).

- Insufficient personnel were authorized for the ammunition platoon (OTEA IER, OT III, users' comments[1]).

- Well-trained map readers are required to perform ammunition resupply (OT III Report, users' comments[1]).

[1] Cummings, M.J., & S.C. Preczewski. "New Kid on the Block," *Field Artillery Journal*, September-October 1983.

Map reading is an example of soldier performance that is important to MLRS success and has been ignored.

AMMUNITION RESUPPLY

Map Reading

- The QQPRI refers to map reading as a requirement for truck drivers but not others, such as platoon personnel involved in vehicle movement.

- There is no indication of any special attention having been given to map reading in terms of doctrinal and operations design, personnel selection, training, etc.

- Concern about the potential constraint of map reading on MLRS effectiveness is reinforced by awareness of the general problem the Army has with map reading skills; for example, in August 1982, GEN Meyers stated that "instruction (in map reading and land navigation) is inadequate ..." and asked the Defense Science Board and ARI to address the problem.

MLRS requirements documents contain reliability, availability, and maintainability (RAM) criteria only for the SPLL. They refer solely to SPLL hardware. Software and soldier problems are excluded in the definition of mission reliability; availability refers to the probability of an SPLL being mechanically ready to engage, not to an SPLL ready with a load of rockets.

RAM

SPLL Requirements

Mission reliability--0.88
(associated with hardware anomalies)

Mean cycles between failures--150

Mean kilometers between failures--535

Achieved availability--0.84

Mean time to repair--crew/organizational--1
(clock hours/repair action) direct support--4

Maintenance ratio--0.5
(man hours/hour)

BITE correct identification of--90%
Line replaceable units (LRU)

BITE false removal of LRC--7%

The SPLL did not attain the system reliability criterion during testing when evaluation was based on the RAM assessment scoring conference. In the data shown below, OTEA used what it believed to be a more acceptable convention for determining mission failure based on hardware failures only. When both hardware and software failures are included, the values drop. Mission reliability based on all operational failures observed reduces them even more. The latter measures are computed differently from the other reliability measures shown and are not directly comparable to them. OTEA considers the SPLL reliability unsatisfactory.

RAM

SPLL Reliability

	System Criterion	OT III FX1	OT III FX2
Mission reliability (hardware only)	.38	.69	.73
System reliability (hardware and software only)		.57	.67
Operational mission reliability*		.37	.47

*Includes mission failures induced by crew and maintenance errors, inadequate manuals, etc.

Achieved availability was measured against a criterion of .84. The improvement for Field Exercise 2 was due mainly to modifications installed by the contractor prior to and during Field Exercise 2 in order to keep SPLLs operational. The operational availability numbers portray a more comprehensive view of availability as they include time spent waiting for maintenance personnel, tools, and repair parts.

RAM

SPLL Availability

	System Criterion	OT III	
		FX1	FX2
Achieved availability Aa	0.84	0.66	0.30
Operational availability Ao	not established by user	0.51	0.64

The MLRS built-in test equipment (BITE) design goal was to identify correctly faults in line replaceable units (LRUs) 90% of the time and to have an LRU false removal rate that would not exceed 7%. Out of a total of 232 possible fault isolation incidents, there were only 23 (15%) correct isolations. Of 54 LRUs actually removed on the basis of BITE indications, 29 (54%) were found to be serviceable.

RAM

SPLL Maintainability

	Maintenance Level	System Criterion	OT III FX1	OT III FX2	DT III
MTTR (clockhours/repair action)	Crew/organization	1	2.53	1.91	.36
	Direct support	4	2.86	2.42	1.78
Maintenance ratio	Crew/organization	.5	.47	.21	Met*
	Direct support		.15	.10	

*Performed by contractor.

Maintainability has a much clearer relationship to the soldier than either reliability or availability. There is an apparent inconsistency resulting from the crew/organization maintenance ratio meeting criteria in the face of (1) mean time to repair (MTTR) exceeding criterion by a factor of about two, and (2) problems in reliability. The crew/organization MTTR may be adversely affected by (1) the inadequate performance shown by BITE in testing and (2) the time required for the organizational mechanic to get to the SPLL, i.e., the need for greater mobility or deployment of mechanics farther forward.

RAM

SPLL Bite

	Design goal	OT III Performance achieved
Correctly identify LRU	90%	15%
False removal of LRU	7%	54%

Because of the fix-forward concept, the conventional four-level maintenance structure may not be well suited to system needs. By designing complexity away from the operator, the resulting system simplification has been at the expense of higher maintenance-level requirements.

RAM

MLRS Maintenance Assessment

- o Maintenance concept preceded advent of system
- o Concept may not be particularly well matched to needs
  --Greater emphasis on forward support required
  --More test equipment needed at GS level
  --Need to combine GS/DS functions
- o Increased complexity at higher maintenance levels
- o De-emphasis on manual backup capabilities
- o Need for greater availability of spares
- o No one individual trained to repair entire SPLL, i.e., the LLM and the vehicle
  --No systems integration manuals for entire system

There are HMPT issues that contribute to RAM inadequacies.

RAM

Soldier Performance

- Excessive time required for maintenance personnel to reach the SPLL. This could be alleviated by changes in O&O concept (move men forward), more vehicles, or more people to be assigned at lower echelons.

- Key battery personnel during OT III focused criticism on the direct support maintenance team chief and assigned mechanics citing lack of experience and poor collective training as possible problem.

- The decision to create a new MOS 27xx (system repairer) for DS maintenance was not made until mid-1981. This was merely a year before DT/OT III.

- At this time DS maintenance training is based on use of actual SPLLs. The decision was made in early 1933 that this was an ineffective approach and work was begun on a maintenance trainer. It is scheduled for delivery to the school by March 1985.

- Despite these concerns about DS maintenance, it was crew/organizational maintenance that failed to meet the MTTR criteria. TRADOC is reviewing the possibility of moving some tasks to direct support.

Total system effectiveness was addressed in requirements documents and serves as a convenient mechanism for summarizing the apparent approach taken in MLRS toward system requirements and test and evaluation.

SYSTEM EFFECTIVENESS

Requirements

LOA	Function of system accuracy, accuracy of target location, system reaction time, and lethality to be postulated during concept definition and demonstrated in advanced development.
System specification	Model to be used for system effectiveness evaluations is described; goals and thresholds are listed for number of launcher loads required to defeat target array.
ROC	MLRS should provide a cost-effective alternative to cannon munitions, specifies use of analytical tools described in system specification.

There was an awareness of the relationship between soldier performance and system performance.

SYSTEM EFFECTIVENESS

Test and Evaluation

- AMSAA in its validation phase IER explored the relationship of system effectiveness to soldier-related functions (e.g., system accuracy, reaction time, ammunition resupply) through the use of modeling techniques.

- Test and evaluation design, data collection and analysis essentially ignored the soldier function in system effectiveness.

The bottom line is that, no matter how much attention may have been paid to HMPT during system development, when it came to the basic issue of comparing requirements to performance and judging the adequacy of MLRS, HMPT was ignored.

SYSTEM EFFECTIVENESS

Soldier Performance

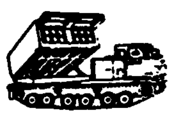
There are no quantitative estimates of the magnitude of the impact of human factors, manpower, personnel, and training problems on MLRS effectiveness.

OUTLINE

Multiple Launch Rocket System (MLRS) Description

Acquisition History

Requirements, Test and Evaluation, and Soldier Performance



Human Factors, Manpower, Personnel, and Training in the Acquisition Process

Major Findings

Training was addressed in requirements documents but in an ambiguous and incomplete fashion. Reference was made to training of soldiers to man the system, but the system was not defined.

TRAINING

Requirements

- The SSG Report, system specification, and ROC all refer, at least briefly, to MLRS training.

- None describes the scope of the system for which training should be provided.

- The ROC describes several training devices. All pertain to training in use of the SPLL, not even maintenance of the SPLL.

It appears that the portion of training addressed in requirements documents turned out reasonably well. Other aspects of training turned out poorly.

TRAINING

<u>Results</u>

- Two CTEAs were conducted which concluded that SPLL crew training was adequate.
- A crash program is underway, scheduled for completion in 1985, to develop a maintenance training device.
- The preponderance of training shortfalls described in this briefing refer to performance <u>not</u> directly related to the SPLL.

There have been at least eight versions of the MLRS Qualitative and Quantitative Personnel Requirements Information (QQPRI). These additions give an idea of how and at what pace manning concepts evolved. For example, it was not until 1981 that it was formally decided that artillery surveyors were needed.

PERSONNEL

QQPRI Evolution

May 1973	Initial QQPRI
May 1980	Radio and communications repairers (31E, 31S, 35E) added at DS/GS maintenance levels
	Ammo specialists (55B, 55D, 55X) added at DS/GS
May 1981	Artillery surveyors (82C) added
	Fire control (45G) and computer repairers (34Y) added
Jan 1983	Electronic repairer (WG-2650) added

These MOS are critical to MLRS. The impact of delaying the MOS 27M decision until 1981 has already been noted.

PERSONNEL

Significant MOS Changes

MOS 15D--is used by LANCE/MLRS crew chiefs only (May 80).

MOS 13M--13B became 13M for MLRS - specific crew members and maintainers (May 80).

MOS 27M--initiated for MLRS system repairer at DS/GS maintenance level (July 81); originally 13B (May 78).

MOS 15J--had MLRS fire direction responsibilities added (May 80).

Such delays not only present problems, but they also are indicators of other issues in the development process, such as the uncertain state of operation and organization concepts.

PERSONNEL

Consequences

What happens when MOS duties are changed, or new MOS are added to the QQPRI 2, 3, or even 5 years after the first QQPRI?

- Personnel cannot be trained on time.
- The system cannot be fully tested, since properly trained people are not there to perform their tasks.
- Development of training devices falls far behind.

SPLL crewmembers (MOS 13M and 15D) have scored higher than other new Army accessions in each of the last 3 years. This is also true for fire direction specialists (MOS 15J). The ability and willingness of the Army to continue to attract people of this caliber for MLRS has not been determined. A formal program should have been instituted to train a broader range of personnel and test their performance to assess the sensitivity of MLRS performance to the quality of personnel.

PERSONNEL

Percentage of Soldiers in Each Mental Category

	13M			15D		
	1981*	1982	1983	1981	1982	1983
I		1	1	2	2	3
II		45	35	23	40	41
IIIa		38	33	27	26	32
IIIb		12	24	33	22	18
IVa		3	6	7	7	6
IVb		1	1	3	2	0
IVc		0	0	1	0	0

	15J			Army-wide		
	1981	1982	1983	1981	1982	1983
I	4	2	2	3	3	3
II	44	52	50	23	30	33
IIIa	18	22	33	16	21	25
IIIb	25	17	13	29	23	28
IVa	8	6	2	16	12	9
IVb	1	1	0	11	6	2
IVc	0	0	0	2	0	0

*MOS did not exist in 1981.

Below is a summary of an analysis recently undertaken by the Soldier Support Center.

MANPOWER

MLRS "Hidden Spaces" (FY 88)

Increased Number of Spaces Needed	MOS	Reason	Where To Get Spaces
52	63T	Poor estimate due to low DPAMMH*	Total force structure?
78	13M	OT III; shortfall identified in firing platoon	Total force structure?
78	13M	OT III; shortfall identified in ammo platoon	Field artillery force structure?
26	15J	OT III; fire direction center	Field artillery force structure?
8	63B	TOE update (Div 86)	Total force structure?
4	63H	TOE update and more accurate DPAMMH* (Div 86)	Total force structure?

TOTAL 246 spaces not planned for across 26 MLRS batteries

*DPAMMH - Direct productive annual maintenance manhours

Source: *SSC*

The 246 unprogramed spaces are about 6% of the 3900 programed spaces scheduled for the MLRS batteries in Division 86. Below is an illustration of the significance of these numbers in operational terms.

MANPOWER

Example: The Ammo Platoon

QQPRI for each battery	3 15D E-6	ammo section chiefs; serve also as NEMTT navigators
	3 13M E-5	assistant ammo section chiefs; serve also as NEMTT navigators
	30 13M	HEMTT drivers and navigators

RESULT

Each HEMTT requires a driver and a navigator to operate. Only 15 out of 18 HEMTT do ammo resupply, because the three section chiefs keep their HEMTT out of action so they can stay forward to keep track of ammo requirements. 15/13 is not enough to keep the battery supplied with ammo.

FIX

3 more 13M HEMTT drivers are being added to TOE.

Sources: *MLRS OT III IER* (November 1983); Users' Observations *(Field Artillery Journal,* September 1983).

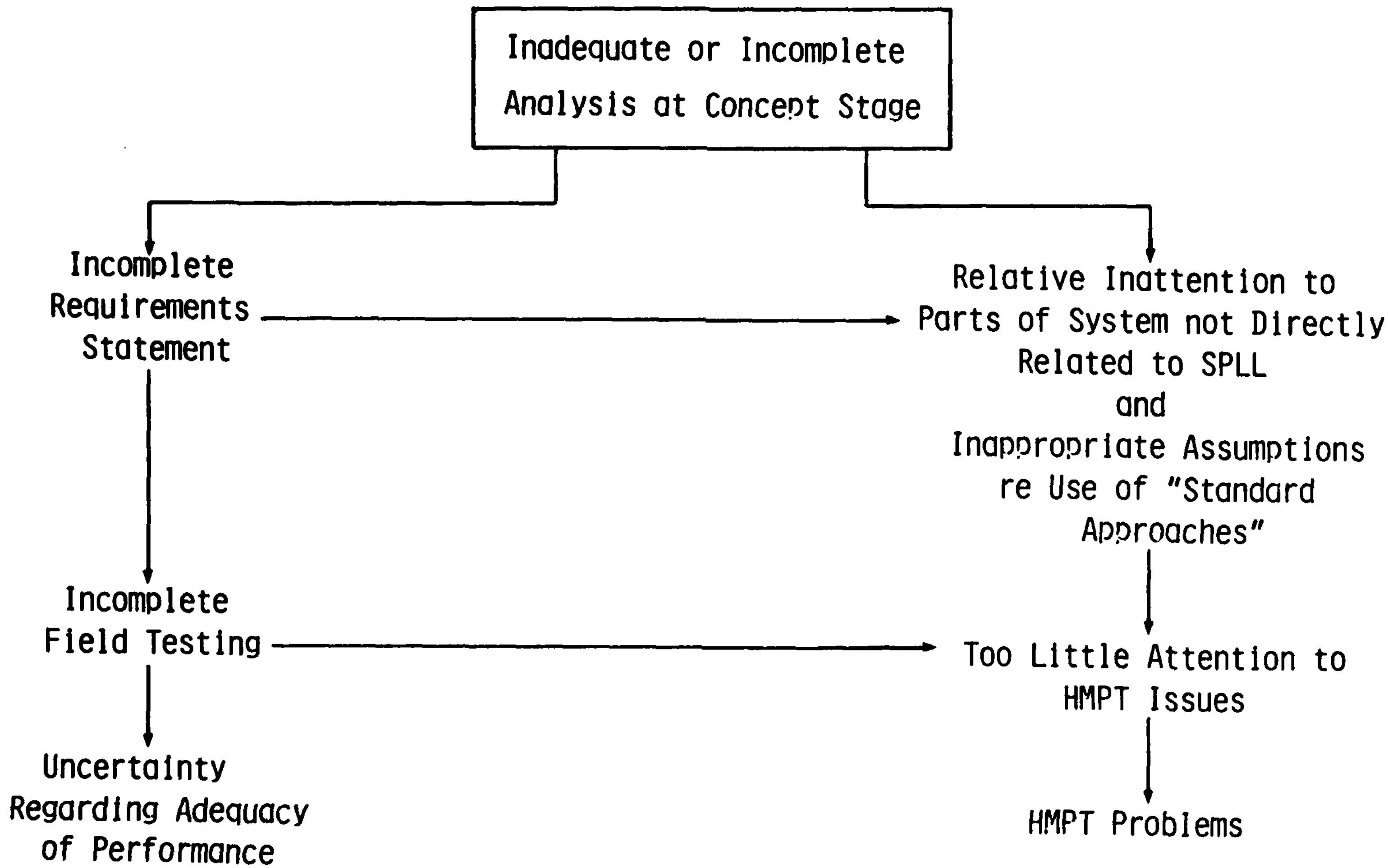
Manpower spaces are converted to a more direct indicator of ammunition resupply capability.

MANPOWER

- Spaces in the ammo platoon have been increased by 8.5% (compared to the 6% average for the battery).
- This produces a 20% increase in HEMTT availability.
- This is obviously a good payoff.
- Why was not this obvious to those responsible for the QQPRI?
- Because the QQPRI does not take into account the complete functioning of the weapon system--the MLRS battery.

What was there about the MLRS development process that led to the performance problems and HMPT issues just reviewed? They appear to stem largely from the same general sequence of events, beginning with an inadequate or incomplete systems analysis at the concept stage. This problem has yet to be completely remedied, as evidenced by the operation and organization concept, which is still not fully developed. For a long time (approximately through the validation phase) attention focused essentially on SPLL hardware. From an HMPT perspective, operation of the SPLL has turned out quite well. Early analysis showed that the three-man crew was adequate; simplicity of design for operations was emphasized and accomplished from the beginning; personnel from the designated MOS can operate the SPLL effectively; and training programs and devices are considered adequate, based on TRADOC Systems Analysis Agency tests, etc. This contrasts with SPLL positioning problems (not strongly hardware-oriented) and the non-SPLL aspects of MLRS.

A CORE PROBLEM FOR MLRS DEVELOPMENT



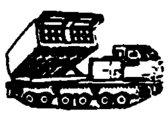
OUTLINE

Multiple Launch Rocket System (MLRS) Description

Acquisition History

Requirements, Test and Evaluation, and Soldier Performance

Human Factors, Manpower, Personnel, and Training in the Acquisition Process



Major Findings

Analysis of the MLRS WSAP has led to many observations, hypotheses, speculations, etc. The major findings for purposes of the Reverse Engineering Project are presented here.

MAJOR FINDINGS

- A comprehensive system description has never been developed for MLRS.
- Requirements and system assessment have been addressed in terms of machine, not man-machine, system performance.
- As a result, it is not clear what performance should be expected of MLRS.
- Nevertheless, there are HMPT problems that affect system performance.
- Most of these problems could have been forestalled if there had been a clear concept of the total system.

Acronyms

ARI	Army Research Institute for the Behavioral Sciences
ASARC	Army System Acquisition Review Council
AMSAA	Army Materiel Systems Analysis Activity
BITE	Built-in test equipment
C^3	Command, Control, and Communications
DSARC	Defense System Acquisition Review Council
DT/OT	Developmental and operational testing
FCS	Fire Control System
FDIS	Fault Detection and Isolation Subsystem
FDS	Fire Direction System
FDTE	Force development testing and experimentation
GSRS	General Support Rocket System
HEMAT	Heavy expanded mobility ammunition truck
HEMTT	Heavy expanded mobility tactical truck
HMPT	Human factors, manpower, personnel, and training
IOC	Initial Operating Capability
LCSMM	Life Cycle System Management Model
LOA	Letter of agreement
LPC	Launch pod container
LRU	Line replaceable unit
MLRS	Multiple Launch Rocket System
MMLRS	Medium Multiple Launch Rocket System
MTTR	Mean time to repair
O&O	Operation and organization
OTEA	Army Operational Test and Evaluation Agency
PLDMD	Platoon leader's digital message device
QQPRI	Qualitative and Quantitative Personnel Requirements Information
RAM	Reliability, availability, and maintainability
ROC	Required Operational Capability
RSV	Resupply vehicle
SPLL	Self-propelled launcher loader
TRASANA	TRADOC Systems Analysis Agency
WSAP	Weapons system acquisition process